Creating Tourism Transport Flow Maps with GIS: A Practical Guide

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Abstract

This paper explores various options to visualize tourism transport flows with spatial analysis tools and show them on maps. To facilitate implementation of these options, procedures for data preparation and map creation are explained through a set of practical instructions. This can give guidance to tourism researchers who are looking for effective ways to map flow data with geographical information systems. Special attention is paid to free and open source software as high costs of commercial software often limit opportunities to study these data. All procedures have been developed and tested using a database of interactions between world regions and some samples of results are shown.

Keywords: flow map, origin-destination table, intra-regional flows, inter-regional flows

Introduction

Flow maps are a mix of maps and flow charts showing movements of objects from one location to another (Phan et al. 2005). Objects may be persons, goods or information. In tourism, examples of such movements are trips by tourists form one country to another or visitor flows in national parks. Researchers studying such movements may wish to visualize them in maps to provide insight into movement patterns, thereby contributing to a better understanding of movement patterns and processes. A good example is the analysis of tourist flows in New Zealand undertaken by Forer (2000). Flow maps also allow exploration of the relationship between flows and other parameters, such as population density. Flow maps strongly enhance insight in the distribution of flows in an area. International tourist flow patterns, especially with regard to air traffic, are critically analyzed in view of their substantial contribution to greenhouse gas emission. These patterns can be investigated on national as well as global scales using arrival and departure data, and estimates can be made of emissions. Becken (2002) used national arrival data to obtain emission figures in order to discuss their increase against the background of sustainable tourist development. More recently, a study on a global scale was undertaken by Peeters and Landré (2012) to

indicate causes and consequences of carbon dioxide emission growth and then evaluate policies to mitigate these environmental impacts of tourism. This paper explores methods for the creation of flow maps and gives detailed instructions to do this. Using a global tourism and transport database (GTTD) of the year 2005, methods had to be found to visualize information on tourist movements within and between world regions by means of flow maps. Much effort went into the selection of suitable software and mapping procedures. In this paper, we want to share our experiences with exploring suitable options to visualize tourism transport flows on a world map.

First we explain the distinction between visual analysis tools and spatial analysis tools and give examples of both. Next we give a short description of the GTTD. The remainder is used to show in a very practical way how we used a number of spatial analysis tools to visualize tourist transport flows, thereby making a distinction between the preparation of flow data and their actual mapping. We start by explaining how tourism flow maps can be created with ArcMap, a well-known commercial desktop GIS. We then move to Flowpy, which as an independent tool improves the flow mapping functionality of GIS software in general. Finally we show how we used Flowmap, a complete spatial analysis toolbox oriented at analyzing networks, to fulfill specific requirements with regard to mapping internal flows. We also show how some necessary GIS commands are implemented with QGIS, a very popular free and open source desktop GIS.

Visual analysis versus spatial analysis tools

With regard to flow representation, a distinction has to be made between visual analysis tools and spatial analysis tools. The latter tools use data which have a geographical reference. They can therefore become part of or linked to geographical information systems (GIS). The former do not have that reference and belong to computer graphics.

We did not test visual analysis tools that create flow maps. However, we had a look at *Flow Map*, (not to be confused with *Flowmap*) developed by a group of researchers of Stanford University's Computer Science Department's Stanford Visualization Group) and *jFlowMap*, recently developed at by a group of researchers of the University of Fribourg and the University of Konstanz (http://graphics.stanford.edu/~dphan/code/flowmap). Both are Java based visual exploration tools that offer very sophisticated views.

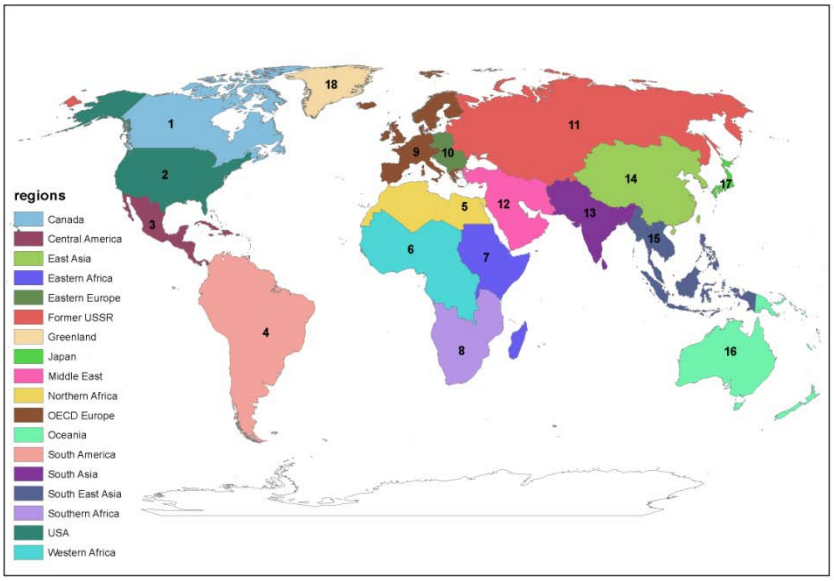

Figure 1. World tourism regions

They have, unfortunately, limited export functionality. Views in *Flow Map* can only be exported in purely graphical formats such as jpg or eps (Phan at al. 2005). Those in *jFlowMap* can only be saved in scalable vector graphics (svg) format (Boyandin et al. 2011). To create a link with GIS software is cumbersome, which is unfortunate as these tools allow extensive visual exploration, such as highlighting flows and nodes and making selections on the basis of magnitude and length, very useful capabilities in flow analysis.

With regard to spatial analysis tools, desktop GIS like *ArcMap* or *QGIS* can do analysis and visualization of spatial data very well, but miss sufficient functionality to handle flows properly as origin and destination points have to be connected by desire lines (straight lines, indicating Euclidian distance, between origins and destination points) showing the magnitude of flows. Fortunately, a number of extensions have been developed for that purpose, which, however, require extensive additional data processing and are only available in commercial software. Partly for this reason, a number of flow mapping software packages have appeared on the market available as freeware. We have tested the following options, including commercial software as well as freeware:

- *ArcMap* with a number of tools from *ArcToolbox*. *ArcMap* is the main component of *ArcGIS*, ESRI's suite of commercial geospatial processing software (http://www.esri.com). *ArcToolbox* is another component.
- *Flowpy* using *ArcMap* or *QGIS* for input and output. *Flowpy* is a *Python* script written by Alan Glennon of the University of California Santa Barbara in 2009

(http://www.enj.com/software). *QGIS* is a popular GIS freeware package (http://qgis.org).

- *Flowmap* (not the same as *Flow Map* mentioned earlier) using *ArcMap* or *QGIS* for input and output. *Flowmap*, originally developed by Tom de Jong at the Faculty of Geographical Sciences of Utrecht University in 1990 for use in developing countries. Over the years, it has been substantially extended with additional functionality and is now a comprehensive spatial interaction software package (http://flowmap.geog.uu.nl).

The global tourism and transport database (GTTD)

The GTTD contains international and domestic trips for 12,568 origin-destination links between and within 221 countries. Each record describes number of trips, average one-way distance between origin and destination, total return distance travelled, and direction of trips. For example, Austria-Belgium and Belgium-Austria are distinct records. Furthermore, the database contains data about total population, GDP per capita and the area of each country (Peeters & Landré 2012). Main sources and methods to build the GTTD are:

- international tourist arrival data per country of origin from the World Tourism Organisation (UNWTO 2007), resulting in 12,118 international flows
- domestic tourist trips per country, based on the relationship between number of trips and GDP per capita
- domestic average distance, based on the relationship between country area and known domestic tourist trip distance averages per EU country (Peeters et al. 2007)
- 15 largest domestic flows redistributed over distance classes, with averages of 200, 400, 600 and up to 6,000 km one-way (Peeters and Landré 2012)
- international distances added by calculating the great circle (shortest) distances using *Great Circle Mapper* (http://gc.kls2.com) and the main entry airports of countries

The GTTD's total number of trips compares well with the figures published by the World Tourism Organisation (UNWTO), which are 3% higher for international trips and 1% higher for all trips (UNWTO-UNEP-WMO 2008). The part of the GTTD used to create tourism flow maps, inter-regional, i.e. between world regions (see figure 1), as well as intra-regional, i.e. within regions, consists of an origin-destination (OD) *Excel* table with columns of origins, destinations, number of trips and average distance (Peeters and Landré 2012).

Creating tourism flow maps with ArcMap

It is possible to create flow maps with *ArcMap* with the help of some tools from *ArcToolbox*. One can decide to split the OD table in two parts, one for intra-regional flows and one for inter-regional flows, or not. It is recommended to split the table. The flow map then distinguishes between inter-regional trips represented by graduated symbols and intra-regional trips represented by proportional symbols. This is visually more attractive.

Data preparation

The original OD *Excel* table was saved in dbf format, after which an attribute selection was done on the OD dbf table, where origin equals destination, to create two new tables, one for intra-regional trips and one for inter-regional trips (see table 1). One also needs a point shapefile with the locations of the centroids of the tourism regions. In *ArcMap*, centroids can easily be extracted from the polygon region file using the *Feature to Point* tool in *ArcToolbox*.

Table 1. Sample of OD table of inter-regional trips (see figure 1 for region codes)

Origin Code	Destination Code	Trips	Average Distance
2	9	15,156,781	6,004
9	15	6,308,508	9,845
9	2	9,686,593	5,853
2	3	29,544,096	1,672
17	2	3,883,906	10,854
9	12	16,480,662	2,533
2	14	3,362,006	11,719
9	10	27,357,425	1,313
16	9	2,118,354	16,778
9	3	4,666,475	7,504
9	4	3,688,043	9,297
2	15	2,390,411	14,257
9	14	3,816,463	8,386
17	9	3,277,735	9,496
9	16	1,582,391	16,719
14	15	7,957,459	3,304
9	5	10,410,679	2,311
15	14	6,319,096	3,384
9	8	2,072,999	8,831
14	9	2,113,690	8,228

Map creation

First the table with the intra-regional trips is joined to the point shape file of region centroids using region code and origin code as common fields. It is advised to make the join permanent by exporting it as a new shapefile and delete unnecessary fields. The layer of this file can now be used to add symbology.

To make a file in order to use its layer to add symbology for the inter-regional flows is more complicated. The following procedure applies:

1. If not done yet, add columns for the x and y coordinates of points to the point shapefile of region centroids using the *Add XY Coordinates* tool in *ArcToolbox*.
2. Join the point shapefile to the table of inter-regional trips using origin code and region code as common field. Make the join permanent by exporting all records as a new dbf file. Then remove the join.
3. Join the point shapefile to the table of inter-regional trips using destination code and region code as common field. Make this join permanent. Do not forget to remove the join.
4. Join the file created in step 3 to the file created in step 2 using OID as common field. Make this join also permanent.
5. Create polylines using the XY to Line tool. The output is a polyline shapefile of all inter-regional flows with their magnitude. As the Robinson projection was used, the polylines will be bent.
6. Join the table of interregional trips to the polyline shapefile using FID and OID as common field and export all features as a new shapefile. This step adds the flow magnitudes to the polyline shapefile (see table 2).

By selecting attributes, selections can now be made to set limits to the flow magnitudes, excluding all flows not fulfilling them. Figure 2, for example, shows all flows larger than one million.

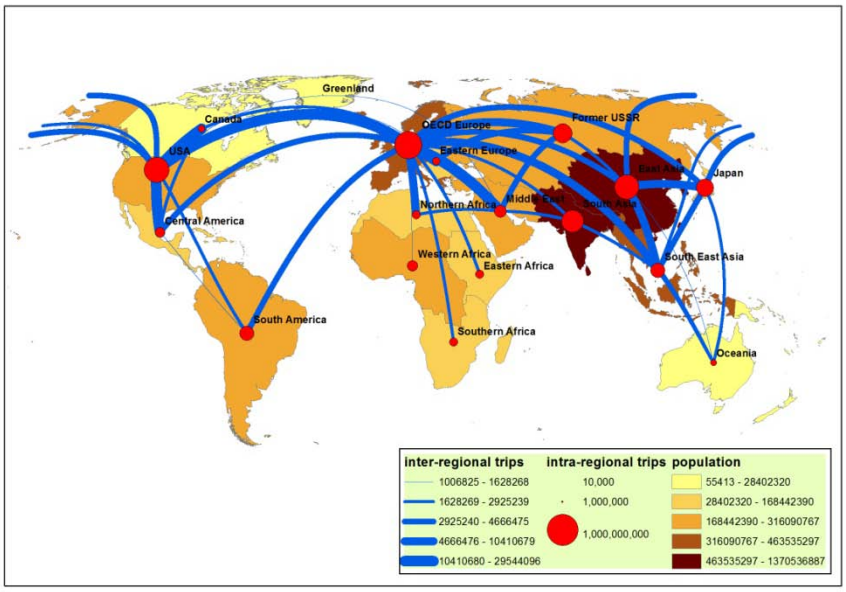

Figure 2. Two-way inter-regional flows; intra-regional flows

Table 2. Sample of OD table with coordinates of interregional trips

X Coord Origin	Y Coord Destination	Y Coord Origin	Y Coord Destination	Origin	Destination	Trips	Average Distance
-9,096,143	4,695,478	644,386	5,644,578	2	9	15,156,781	6,004
644,386	5,644,578	10,298,277	847,935	9	15	6,308,508	9,845
644,386	5,644,578	-9,096,143	4,695,478	9	2	9,686,593	5,853
-9,096,143	4,695,478	-8,958,626	2,308,280	2	3	29,544,096	1,672
12,123,293	4,008,124	-9,096,143	4,695,478	17	2	3,883,906	10,854
644,386	5,644,578	4,209,397	3,107,806	9	12	16,480,662	2,533
-9,096,143	4,695,478	9,098,104	4,041,301	2	14	3,362,006	11,719
644,386	5,644,578	1,723,994	5,042,911	9	10	27,357,425	1,313
12,454,420	-2,690,707	644,386	5,644,578	16	9	2,118,354	16,778
644,386	5,644,578	-8,958,626	2,308,280	9	3	4,666,475	7,504
644,386	5,644,578	-5,604,082	-1,564,097	9	4	3,688,043	9,297
-9,096,143	4,695,478	10,298,277	847,935	2	15	2,390,411	14,257
644,386	5,644,578	9,098,104	4,041,301	9	14	3,816,463	8,386
12,123,293	4,008,124	644,386	5,644,578	17	9	3,277,735	9,496
644,386	5,644,578	12,454,420	-2,690,707	9	16	1,582,391	16,719
9,098,104	4,041,301	10,298,,277	847,935	14	15	7,957,459	3,304
644,386	5,644,578	953,687	2,970,772	9	5	10,410,679	2,311
10298277	847935	9098104	4041301	15	14	6319096	3384
644386	5644578	2405059	-1905800	9	8	2072999	8831
9098104	4041301	644386	5644578	14	9	2113690	8228

Creating tourism flow maps with Flowpy

Flowpy was intended to replace *Data Model Tools* (*FDMT*), an *ArcMap* application developed by Glennon in 2005. It is an adaptation of *Tobler's Flow Mapper*, built within the framework of the Geographic Initiatives Project by a group of researchers from the University of California Santa Barbara, University of Oklahoma and University of Utah (Glennon and Goodchild 2005). *FDMT* as *ArcMap* application could only function on specific versions of this software. Therefore, Glennon reprogrammed it as a *Python* script, functioning independently. We have used this script to visualize the flows related to the database. It generates a polyline shapefile, which can be added as a layer in a desktop GIS to create symbology and eventually a flow map. *Flowpy* can only be used after additional installing *Python 2.6*, *GDAL* and *Python/GDAL* bindings. The procedure to do this is fast and well-explained in the software instructions.

Data preparation

For this option, the original OD *Excel* table has to be transformed to a square matrix using *Data > PivotTable* and *PivotChart Report* (see Annex 1 for procedure). The only task left is that all the blank cells in the square matrix must be converted to zero (see Annex 2 for procedure).

The worksheet is now ready for conversion to space delimited text (see table 3). To create sufficient space between columns, column width has to be set to a suitable number of digits. Save then as *Formatted Text (Space Delimited)*. If conversion does not succeed because of a size limit set by the software, one can open the worksheet in Access and then save from there as space delimited text. A second data file needed for the second option is a file (see table 4) containing the point coordinates of the origins (see Annex 3 for procedure).

Table 3. Sample of input interaction file (origins in rows and destinations in columns)

	1	2	3	4	5	6	7
1	45,477,126	14,862,000	2,042,426	263,753	111,005	38,059	40,836
2	14,406,441	628,606,910	29,544,096	1987,258	298,322	119,192	149,761
3	331,269	14,496,093	91,627,354	423,547	23,986	57,010	421
4	128,567	1,820,239	1,006,825	215,145,633	48,914	31,768	1,828
5	23,660	44,003	110,948	635	69405,844	145,547	2,680
6	12,726	92,520	334,533	14,078	130,990	119,103,001	7,407
7	8,642	28,247	8,260	207	154,764	129,590	72,916,314

Table 4. Coordinates of origins and destinations (world regions)

Region	Code	X Coordinate	Y Coordinate
Canada	1	-7,352,159	6,271,812
Central America	3	-8,958,626	2,308,279
East Asia	14	9,098,104	4,041,300
Eastern Africa	7	3,409,844	705,380
Eastern Europe	10	1,723,993	5,042,911
Former USSR	11	6,623,286	6,096,767
Greenland	18	-2,671,327	7,574,787
Japan	17	12,123,293	4,008,123
Middle East	12	4,209,397	3,107,805
Northern Africa	5	953,686	2,970,772
Oceania	16	12,454,420	-2,690,707
OECD Europe	9	644,385	5,644,577
South America	4	-5,604,082	-1,564,097
South Asia	13	6,995,799	2,735,142
South East Asia	15	10,298,277	847,935
Southern Africa	8	2,405,058	-1,905,799
USA	2	-9,096,143	4,695,478
Western Africa	6	811,329	1,023,886

Map creation

The script written by Glennon uses a square interaction matrix and corresponding coordinate pairs of the nodes to calculate three flow types: two-way flow, i.e. a one-directional flow together with a reverse-directional flow, gross flow, i.e. the sum of a one-directional flow and a reverse-directional flow, and net flow, i.e. the difference between a one-directional flow and a reverse-directional flow. It needs two script files as well as two space-delimited text files, namely an input point file and an input interaction file. The names of the two data files and the paths to them must be indicated in the interface as well as the type of flow calculation needed, and the name of and path to the output shapefile.

The original spreadsheet of flow data contains an interaction matrix that can be separated in three parts: a left diagonal containing the intra-regional flows, a lower subtriangle containing the inter-regional one-directional flows and an upper subtriangle containing the inter-regional reverse-directional flows. This separation can be implemented using the *Excel* add-on *BigMatrix.xla*, called *Linear Algebra for Big Matrices*, developed by Volpi of Foxes Team (http:/digilander.libero.it/foxes).

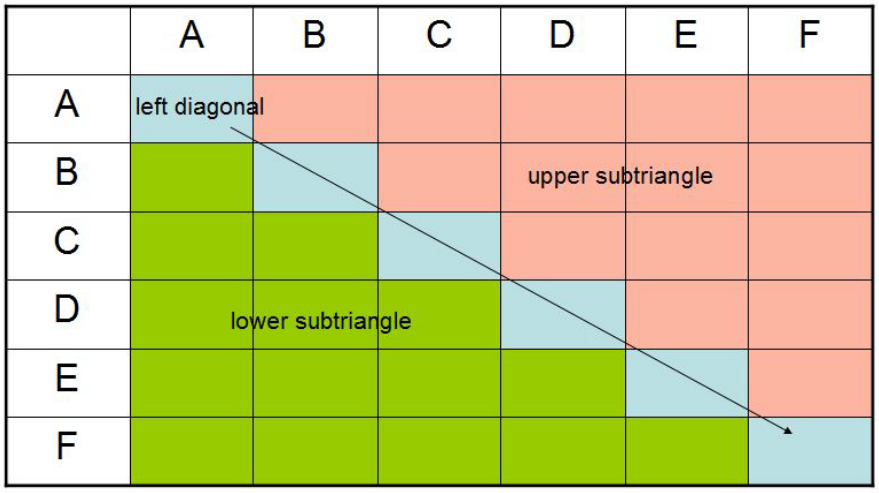

Figure 3. Component of square interaction matrix

Three new spreadsheets are created in this way, one for each component of the original interaction matrix, which are then saved as text files for use as input in *Flowpy*. This script is then able to create shapefiles for different flow types: two-way flows, one-directional flows, reverse-directional flows, intra-regional flows, gross flows and net flows. Initially, two-way, gross and net flows include intra-regional flows if they are part of the interaction matrix. To exclude the latter flows, the lower subtriangle must be added to the upper subtriangle and then saved as a text file.

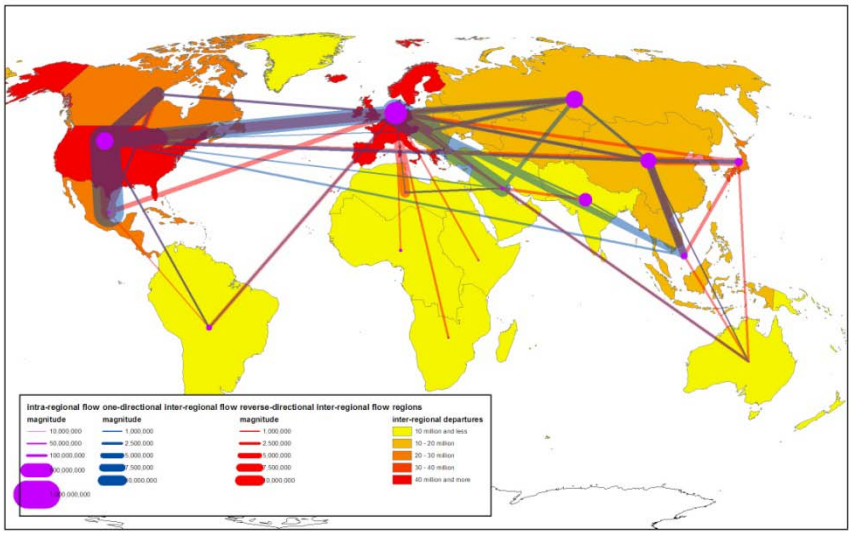

Figure 4. One-directional and reverse directional inter-regional flows; intra-regional flows

After the shapefiles have been added as layers in a desktop GIS, symbology can be added with *ArcMap* or *QGIS* to visualize the flows. Figure 4 shows a map created with *ArcMap*, visualizing the inter-regional flows in two directions by making both of them transparent.

Creating tourism flow maps with Flowmap

Flowmap has a multitude of spatial analysis functions. As it specializes in the display, analysis and modelling of spatial interaction (De Jong and Van der Vaart 2010), it can also display flow data using straight lines or wedges.

Data preparation

For the option of using Flowmap to visualize flows, at least two files must be created (if origins and destinations are the same), namely a file named *???????1.dbf* for the locations of origins and destinations and a file named *???????2.dbf* for the magnitude of flows. The structure of the point file is label – *xcoordinate* – *ycoordinate*, and that of the flow file is *score* – *label1* – *label2*. *Label1* is the flow origin and *label2* the flow destination. Both labels must appear in the origin and destination files. Point files can be derived from the point shapefiles with columns for the x and y coordinates (created with *ArcMap* or *QGIS*), whereas for flow files the original OD table is used by changing the order of the columns and removing the column of the average distance.

Map creation

In *Flowmap*, one has to create a project first. In each new project, an origin file, destination file (they can be the same) and flow file must be specified. These files are in dbf format. The origin and destination files contain the coordinates of origin and destination points respectively, whereas the flow file contains the magnitude of each flow or desire line, a reference to its origin and a reference to its destination. A great advantage of *Flowmap* is that it can handle very large datasets. It also has an extensive flow symbology, part of which can be exported. Unfortunately, *Flowmap* does not take intra-regional flows into account.

To show he difference in map quality between *Flowmap* and *ArcMap*, the largest international flows of Dutch holiday makers, with the countries of destination showing total distance travelled, were visualized with *Flowmap* (see figure 5) as well as with *ArcMap* (see figure 6), created with *ArcMap*. The destination countries are colour coded as based on total transport volume of Dutch tourists in passenger kilometers. Flowmap also has certain disadvantages. Figure 6 shows that the range of colouring in *Flowmap* is very limited compared to that of *ArcMap*. *Flowmap* also builds its symbology in a linear procedure, making editing more complicated. If it is necessary to make changes, one has to start a new procedure. Furthermore, *Flowmap* can only save a map in jpg and bmp graphics formats and the resolution of such maps is limited (De Jong and Van der Vaart 2010).

The above-mentioned shortcomings of *Flowmap* can be removed by developing a procedure to create intra-regional flows and using the output of *Flowmap* as input in a desktop GIS for

visualization purposes. This procedure also allowed us to create added value by making these flows comparable with inter-regional flows.

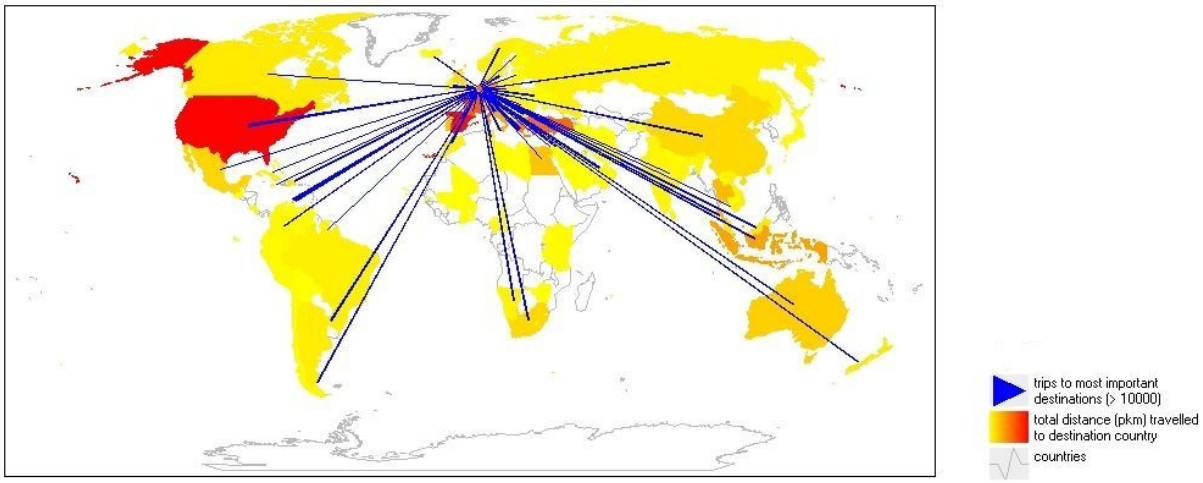

Figure 5. Largest international flows of Dutch holiday makers visualized with *Flowmap*

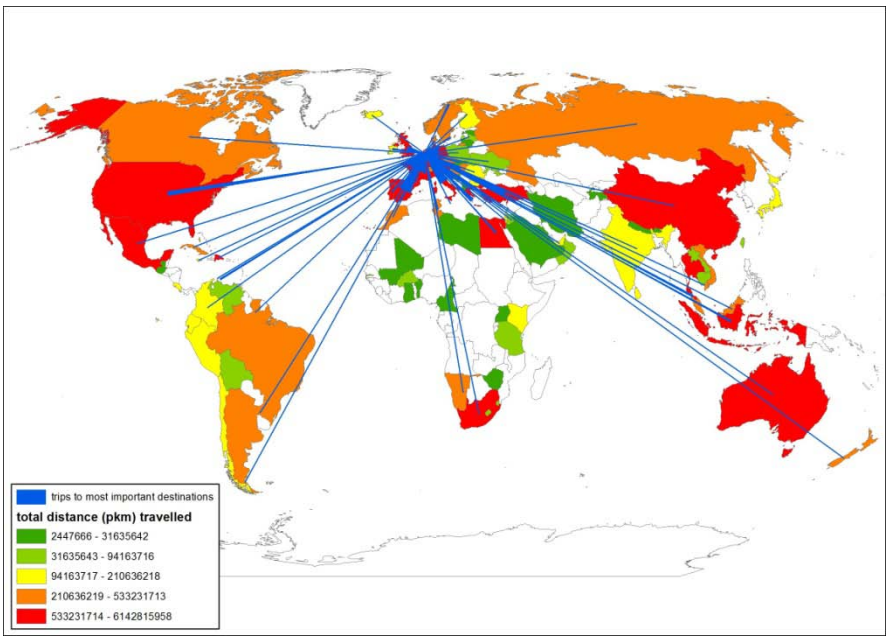

Figure 6. Largest international flows of Dutch holiday makers visualzed with Arcmap (source: Peeters and Landré 2012)

The procedure to create intra-regional flows in *Flowmap* is as follows:

1. Differentiate between origin file and destination file
2. Change the codes by adding O in origin file and D in destination file
3. Add a field and adapt the coordinates using the equation dC = (√/4)*AVDIST*100

4. Deduct dC in the origin file from x and y coordinates for all records
5. Add dC in the destination file to x and y coordinates for all records
6. Replace the original coordinates with these new coordinates
7. Create a project in *Flowmap* by specifying, origin file, destination file, flow file and flow export file
8. Use wedges and customize flow symbology by making the arrow shaft proportional and by setting the width
9. Display flows on a map by drawing desire lines from the flow file

The export file, created by *Flowmap* in bna format, can be converted to mif (MapInfo Interchange) format. One can then use the *MIFToShape* tool in *ArcToolbox* to convert this file to a shapefile. Alternatively, this mif file can be added in *QGIS* as a vector layer and saved as a shapefile. The intra-regional flows can now be visualized with a desktop GIS (see figure 7). They are shown in opposite directions, from SW to NE and from NE to SW, to indicate that such flows, like inter-regional flows, have an origin and destinations at different locations, although inside the region. To get these flows into the opposite direction, origin and destination files must be switched in *Flowmap*. Flow magnitude is, similar to inter-regional flows, indicated by the width of wedges. A great advantage of this procedure is that distances of intra-regional flows can be shown by their length using average distance as an indicator.

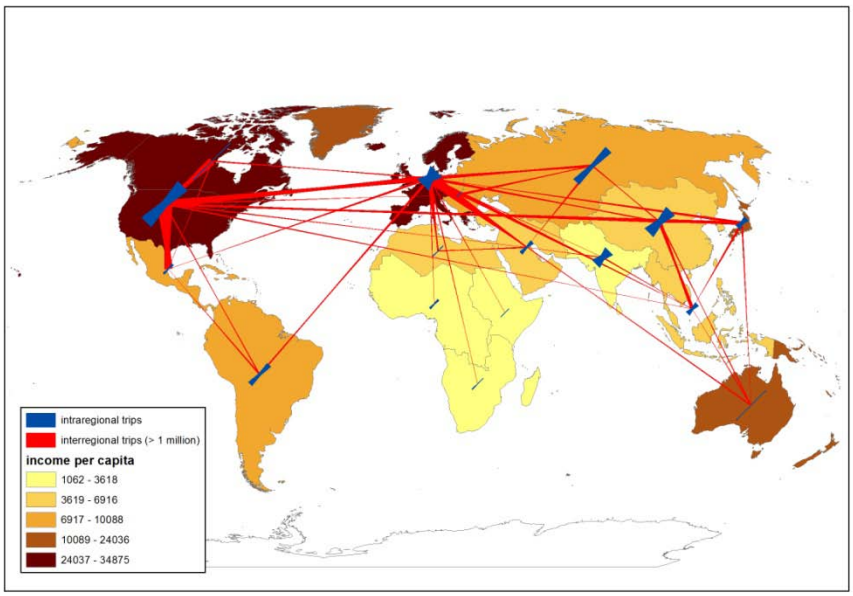

Figure 7. Two-way inter-regional and intra-regional flows between world regions (source: Peeters and Landré 2012)

Having spatial and attribute data in a desktop GIS at this stage, makes it easy to undertake what-if scenarios. Figure 8, for example, shows the same flows as in figure 7, but with trips with distances larger than 6,000 km proportionally redistributed to departures per country over all trips shorter than 6,000 km, thus keeping total number of trips constant, while at the same time reducing total distances covered. The latter is important with respect to reducing tourism's contribution to climate change (Peeters and Dubois 2010).

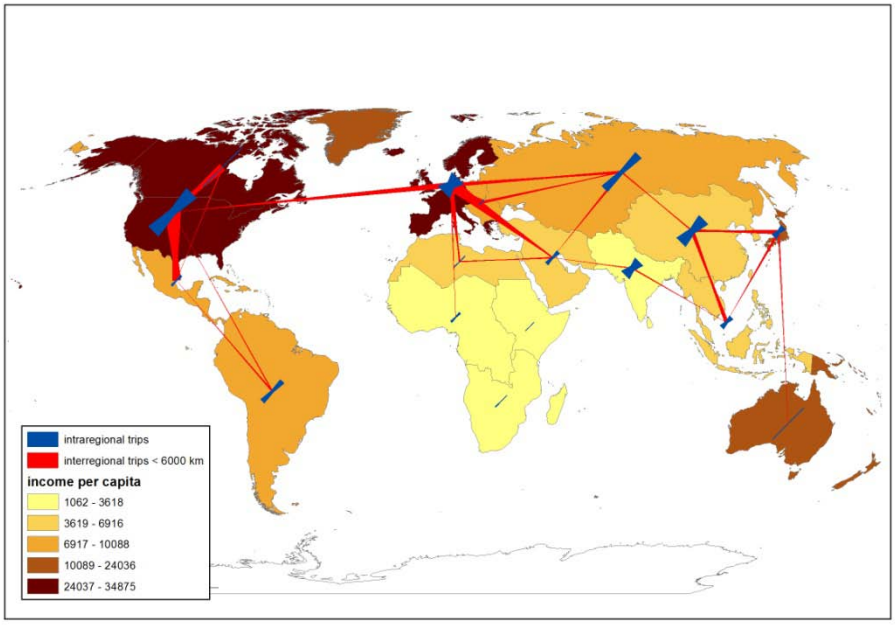

Figure 8. Two-way inter-regional and intra-regional flows between world regions limiting the distance of inter-regional trips to 6,000 km (source: Peeters and Landré 2012)

Conclusions

Researchers in the field of tourism and transport might benefit from the visualization of tourism flows. Without such visualization it is more difficult to really comprehend the distribution of tourism flows, to easily find possible relationships with other spatial information and to determine the significance of some flow. Visualization is first of all valuable to generate hypotheses about how the tourism system works and how it is related to other spatial parameters. But it also helps to show the extent of tourism. For example, in studies on the role of tourism for developing countries, simple flow maps would show easily this role to be very small (see figure 7). Furthermore, flow maps are invaluable for education, giving a memorable imprint of the situation in one clear figure, while showing tables with long ranges of numbers will not stick very long to the reader's memory. The value of GIS software in this regard is still underestimated due to lack of information about its functionality and a perception that it is too technical for use in the tourism field. The

main purpose of this paper is to empower tourism researchers who lack the necessary skills to map flows on the basis of spatial data and allow them to visualize flow patterns using various methods. Flow maps can provide much added value to origin-destination tables and can show more insight in changes in flow patterns. Our advice is strongly founded on our experiences in recent research (Peeters and Landré 2012). Unfortunately, there are no straightforward procedures to create flows on the basis of an OD table. Various software products are available that support the necessary additional tasks. We have indicated three options that do not require any programming skills. To use one of these options, one has to prepare the data input exactly as prescribed by the software.

ArcMap provides extensive facilities to create flow maps and does not need external tools. Its freeware alternative, *QGIS*, cannot create desire lines from points, but has excellent data processing and mapping functions that rival those of *ArcMap*. *Flowpy* and *Flowmap* extend the functionality of GIS desktop software for handling flows. Therefore, it is recommended to create flow maps with *QGIS* using them as external tools.

There are also different ways to handle flows. One can differentiate between intra-regional and interregional flows and use different types of symbology. One can also differentiate between two-way flows, gross flows, net flows, one-directional flows and reverse-directional flows. There are also various options to visualize intra-regional flows. Furthermore, flows (the width of the symbols showing the flows) have been shown here to represent the number of trips, but can also easily be used to show number of passenger-kilometers travelled or total amount of CO_2 emissions as well as economic parameters like flows of revenues. The space for creativity is large and much depends on the purpose of the mapping process and the conditions set for visualizing flows.

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Annex 1: Procedure for transformation of OD Exel table to a square matrix

1. Using the wizard, in step 1, select *Microsoft Office Excel list or database* and select *PivotTable*, then click *Next*.
2. In step 2, indicate the data range and click *Next*.
3. In step 3, select *New worksheet* and click *Finish*.
4. Drop *Origin items* in section *Drop Row Fields Here*, drop *Destination items* in *Drop Column Fields Here* and drop *Sum of Trips* in section *Drop Data Items Here*.
5. Copy the trip data without the row and column totals and paste them to a new worksheet.

Annex 2: Procedure of conversion of blank cells in a square matrix to zero

1. Select the cells with trip data
2. Click *Edit* and then *Go To*
3. Click *Special*

4. Select *Blanks* and then click *OK*. All blank cells have now been selected.
5. Click *Edit* again and then *Replace*
6. Enter 0 in the *Replace with* box and click *Replace All*
7. All former blank cells now contain zeros. Click *OK*

Annex 3: Procedure for the creation of a file containing point coordinates of origin

1. In *ArcMap*, find the centroids of the regions using the Feature to Point tool (in *QGIS*, use *Vector > Geometry Tools > Polygon centroids*).
2. Add the coordinates of these centroids to the data file using the Add XY Coordinates tool (in *QGIS*, use *Vector > Geometry Tools > Export/Add geometry columns*).
3. In *Excel*, open this file in dbf format, copy the coordinates to a new worksheet and set the width of the columns with *Format > Column > Width*).
4. Save this worksheet as *Formatted Text (Space Delimited)*.